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Worldwide Detection Capability of a Prototype Network of Seismograph Stations

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LEXINGTON, MASSACHUSETTS

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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WORLDWIDE DETECTION CAPABILITY OF A PROTOTYPE NETWORK OF SEISMOGRAPH STATIONS

R. E. NEEDHAM

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ABSTRACT

An investigation into the detection capability of a prototype seismic network composed of a 32 station subset of the approximately 150 stations used by the ISM experiment has been completed. This investigation was threefold in nature. The first investigation directly compared the lists of events produced by the 32 station network experiment, the USGS-PDE, and the ISM experiment for the ISM time period, 20 February 1972 to 19 March 1972. The number of stations used, the quality of available data and events acceptance criteria were not the same for all three lists. The comparisons determined the effects the different input data and acceptance criteria had on the number of events reported and the relative location accuracy of each. Secondly, an investigation to directly determine the effect a careful reading of seismograms had on the performance of individual stations and/or small networks was conducted. To evaluate the improvement in performance for single stations, 2 stations were selected and reread. The reread detections were compared to the detections that were reported to the USGS for all ISM events that were within the distance range between 20° and 90° from the station. These comparisons help verify that a significant number of valid and clear arrivals are not reported to USGS. To evaluate the impact on network performance 21 stations of the 32 station network were reread for a small number of events to determine the extent to which the rereading of the seismograms could change the detection and locating capabilities of a small network. The final investigation, to compliment the experimental

evaluations was to program a simple statistical model to predict the probability of an N station detection from an M station network with a known average station probability. The data from the 32 station set were used to estimate the single station detection probability for events with m_b magnitudes of 4.6 but less than 4.7 within a distance of 90° or less from the station. This probability was entered into the model and a network detection probability table was generated.

Introduction

In January 1972 a group of seismologists from several countries met in Cambridge, Massachusetts, to discuss problems related to the seismic detection and identification of underground nuclear tests. It was decided that a cooperative attempt be made to better assess the capabilities of deployed seismic instrumentation for monitoring world wide seismic activity. The period from 20 February to 19 March 1972 (the International Seismic Month-ISM)[1,2,3,4,5] was selected for this experiment with the Lincoln Laboratory acting as a data center.

A list of 996 seismic events were reported by Lincoln Laboratory[5] as a result of the experiment. A secondary result of the ISM experiment has been the evaluation of the capability of a small network of stations to monitor global seismic activity. Thirty-two seismic stations from the approximately 150 used in the ISM experiment were selected to be evaluated as a small network. The 32 stations were chosen ad hoc to give good global coverage while using stations which contributed data to a large number of ISM events. The results of an in depth comparison of the list of events produced using the network, the ISM experiment list, and the USGS PDE list (United States Geological Survey - Preliminary Determination of Epicenters) are given below. To better evaluate the detection capability of a small network of 32 stations, two additional interrelated experiments were also completed and are reported below. One of these experiments relates to the improvement which can be achieved in the event detection capability of individual stations which report to

the USGS by a more exhaustive reading of the seismograms. The other was a simple theoretical study of a small network's probability of detecting and locating an event.

The three lists discussed in this report are composed of events occurring during the ISM experiment time period, 20 February 1972 through 19 March 1972. The methods used and the parameters needed for an event acceptance for each of these lists are as follows:

USGS PDE List

The USGS uses arrival times from approximately 600 seismograph stations to prepare its event list. The criteria required for event acceptance are that at least five station initial arrival times (P or PKP) are associated from at least two different azimuths. For near regional events, phases P_n, P_g, S_n, and S_g can be accepted. Not all events meeting these acceptance requirements are necessarily reported. An event can be rejected at the discretion of a USGS analyst who reviews the data.

ISM List

The ISM experiment used data reported to USGS only for stations which reported at least 50 times during the ISM period. This requirement eliminated a large majority of the stations that report to the USGS, leaving approximately 150 stations used for the ISM experiment. All of the stations used in the computation of events by the ISM experiment, with the exception of stations CHG and YKA, were contributers to the PDE computations, but not necessarily at the same detection level. The detections which the USGS used from

the two large arrays, NAO and LAO, were from the published processed event bulletins. The ISM experiment used these plus preliminary detection logs which contained many arrivals which do not appear in the site bulletins. Data from the array YKA were not reported to the USGS but all detections were processed for use in the ISM experiment. Swedish seismologists reprocessed HFS data and reported many more arrivals to the ISM experiment than were reported to the USGS. All Canadian stations were reread by personnel of the Seismological section of the Canadian Department of Energy, Mines and Resources, and these were used in the ISM experiment. The number of reread detections from the Canadian stations greatly exceeded the number of detections sent to the USGS. The stations KBL and CHG were reread from film chips by an analyst within the Lincoln Laboratory group. The detections for the rest of the stations used in the ISM experiment were exactly the same as were reported to the USGS.

The ISM experiment event acceptance criteria differ from the PDE requirements in that only 4 detections, instead of 5, are required and they need not be just initial arrivals of phases P or PKP. The ISM locate program accepts phases P, PP, PcP, ScP, pP, 3 branches of PKP, 3 branches of PKKP, SKP and P'P' detections. Also listed as acceptable detections are array computed $dt/d\Delta$ and array computed azimuths. The ISM experiment also requires that at least one of the associated stations have a distance $> 3^{\circ}$ from the epicenter.

Fig. 1. Geographic distribution of prototype network stations. Not shown on this map is station SPA (South Pole, Antartica).

The final acceptance of events listed on the ISM list was at the discretion of Lincoln Laboratory analysts after reviewing the event location parameters.

32 Station List

The seismic stations selected to make up the 32 station network are listed on Table 1 and a map showing their geographic distribution is shown on Figure 1. This 32 station network is a subset of the ISM network and the event acceptance criteria were the same as for the ISM list. For a given station the same detections were available as for the ISM experiment. No new detections were added.

Table 1
32 Station Network

LAO	LASA Array, Montana
YKA	Yellowknife Array, N. W. Terr. Canada
UBO	Unita Basin Observatory, Utah
NAO	NORSAR Array, Norway
HFS	Hagfors Array, Sweden
MBC	Mould Bay, N. W. Terr. Canada
KBL	Kabul, Afghanistan (WWSSN)
ASP	Alice Springs, N. Terr. Australia
MAT	Matsushiro, Honshu, Japan (WWSSN)
COL	College Outpost, Alaska (WWSSN)
CHG	Chengmai, Thialand (WWSSN)
PNS	Penas, Bolivia
CTA	Charters Towers, Queensland, Australia (WWSSN)
BLC	Baker Lake, N. W. Terr. Canada
NUR	Nurmijarvi, Finland (WWSSN)
TUC	Tucson, Arizona (WWSSN)
FBC	Frobisher Bay, Canada
GBA	Gauribidanur Array, India
SPA	South Pole, Antarctica (WWSSN)
PMG	Port Moresley, New Guinea (WWSSN)
KIC	Koson Boka, Ivory Coast
CLL	Collmberg, E. Germany
SSF	Saint Saulge, France
BDF	Brasilia Array, Brazil (WWSSN)
BNG	Bangui, Central Africa Rep.
QUE	Quetta, Pakistan (WWSSN)
SHI	Shiraz, Iran (WWSSN)
BAG	Bagulo City, Philippines (WWSSN)
BUL	Bulawayo, Rhodesia (WWSSN)
AFI	Afiamalu, Samoa (WWSSN)
EZN	Ezine, Turkey
SHL	Shillong, India (WWSSN)

Event List Comparisons

The PDE list contained 353 events for the ISM time period. Only two of these did not appear in the ISM list. The two events not reported in the ISM list were a small Alaskan event with no reporting station greater than 3° from the epicenter and a small South African event which required the use of phase P_g, an option which the ISM locate program did not have.

If the USGS had used only the data submitted to them from stations that were used by the ISM experiment, then 346 events would have met the PDE event requirements. The seven events that would not have been reported, were small events detected and located by a network of close-in stations to the epicenter, in most cases <10°. Four of these seven events had no magntiude computed while the other three had magnitudes of 3.8, 3.8, and 4.9, with the 4.9 m_b being a single station value for a station 10° from the epicenter.

We don't know how many events the USGS would have obtained if they had limited themselves to the stations used by the ISM but had used all phase and velocity information reported to them. However, a check of three months of data reported and entered into the PDE hypocenter system[7] indicates that a monthly average of 11,303 secondary phases, 1741 array computed velocities and 1741 array computed azimuths could have been added to the initial arrival detection base used by USGS for event association and acceptance.

Of the 353 PDE events, 308 could be located using data from the 32 station subset and using ISM event acceptance criteria. A histogram of the ISM AVEMB (average m_b magnitude) of the 43 events reported by the PDE list but not reported by the 32 station list is shown in Figure 2. The shaded portions of Figure 2 are events which had one or less individual station m_b's averaged into AVEMB. One can note that only 2 events with an m_b greater than 4.5 were not reported by the 32 station list, and each of these events have a questionable single station AVEMB value.

The ISM list is composed of 996 events which occurred during the ISM period. Of these 996 events, 787 events satisfy the USGS event acceptance criteria. This increase of 434 events over the 353 reported on the PDE list is due to the improved reporting of the $\approx$ 25 reread stations. A histogram of the ISM AVEMB distribution of the 643 events not reported by the USGS is shown in Figure 3. The shaded portion denotes the events that had data from less than 2 stations used to calculate the AVEMB. The majority of the events greater than 4.8 m_b are events with single station m_b values which are always somewhat questionable.

The 32 station network, using ISM event acceptance criteria reported 818 of the 996 events reported on the ISM list. Of these 818 events 460 would have been reported if the event acceptance requirements of the USGS had been used. This increase of 107 events over the 353 events reported by the entire USGS network on the PDE list is due to improved detection from only 4 arrays and 5 single stations. The USGS, using the

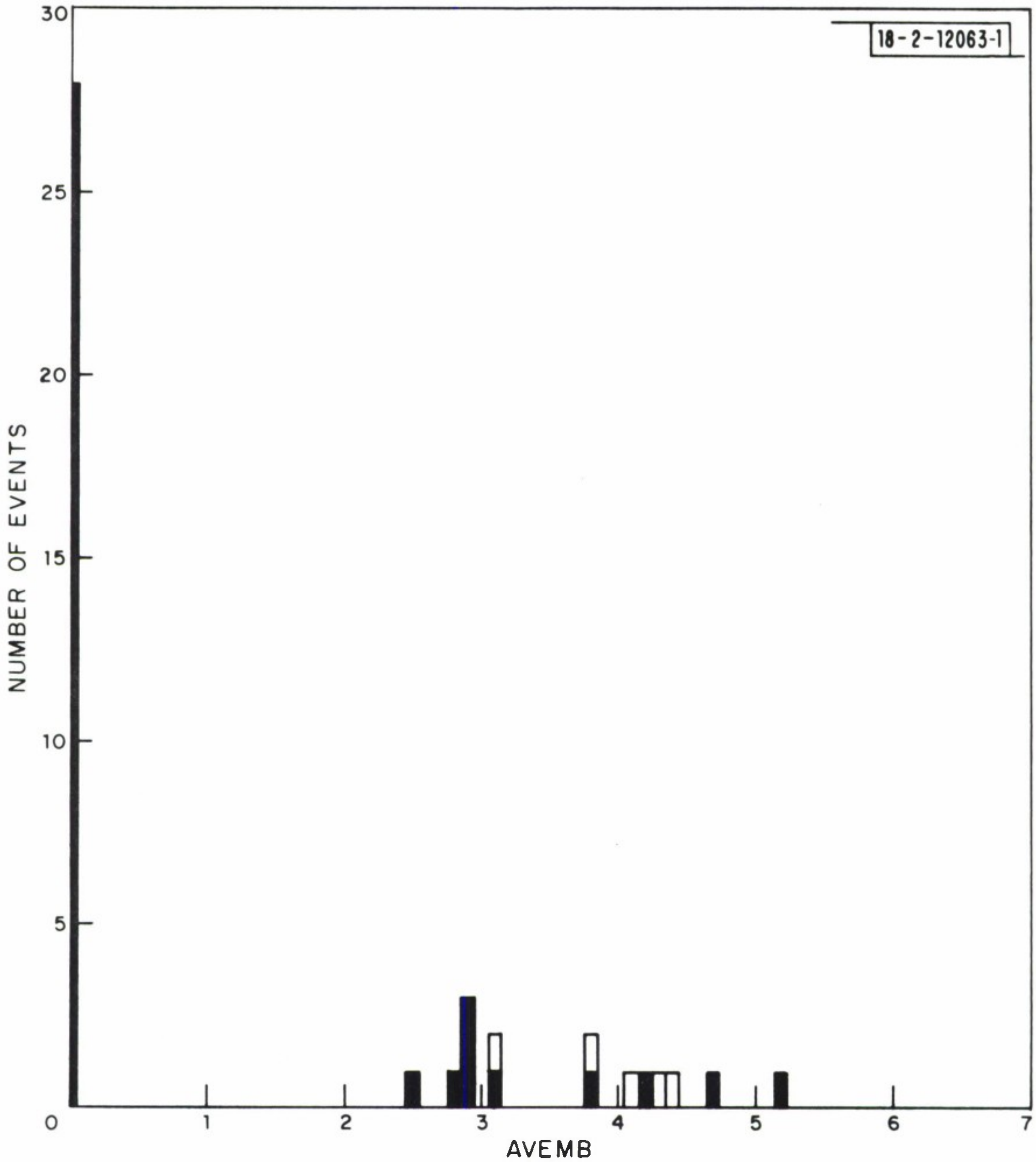

Fig. 2. Magnitude distribution of PDE events not reported by the prototype network.

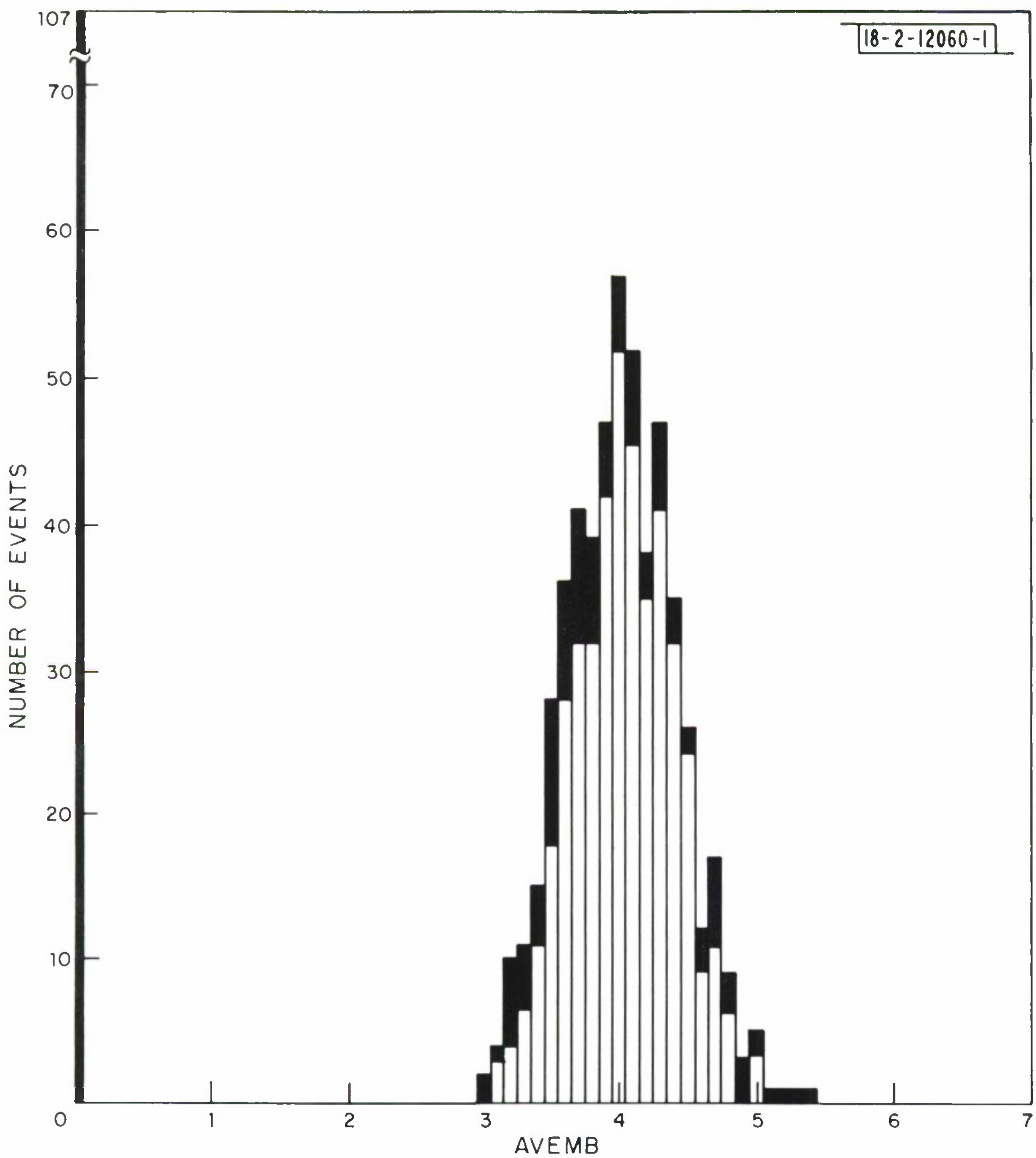

Fig. 3. Magnitude distribution of ISM reported events not reported by PDE.

detections from these 32 stations which were reported to them would have reported only 254 events. A histogram of the ISM AVEMB distribution of the 508 32 station list events not reported by the USGS is shown as Figure 4 with the shaded portion being events with the less reliable single station average m_b values. The number of events reported on the 32 station list was 177 events less than the number of events on the ISM list. A histogram of the ISM AVEMB distribution of these events is shown as Figure 5. Only 23 of the 177 events have an average m_b that used 2 or more station m_b's in its average. Many of the 177 events of the ISM list and the 43 events of the PDE list, not reported by the 32 station list, were small events requiring a more compact geographically distributed network than the 32 station network to meet event acceptance criteria of this experiment.

To determine the accuracy of the epicenter locations reported on the ISM list of events and the 32 station list of events, the following comparisons were made. A direct comparison of the epicenter location parameters of the 351 events common to both the PDE list and the ISM list was made which indicated that 99% of the ISM event epicenters were within 1° of the PDE epicenters. As was previously stated, 787 of the 996 ISM events would have satisfied the USGS PDE event acceptance criteria. Assuming that the extra 436 events would therefore have locations as good as those of the 351 directly compared events we conclude that these 787 ISM events would have epicenter locations within 1° of the PDE epicenters. Using this expanded base of reliable epicenters, a direct

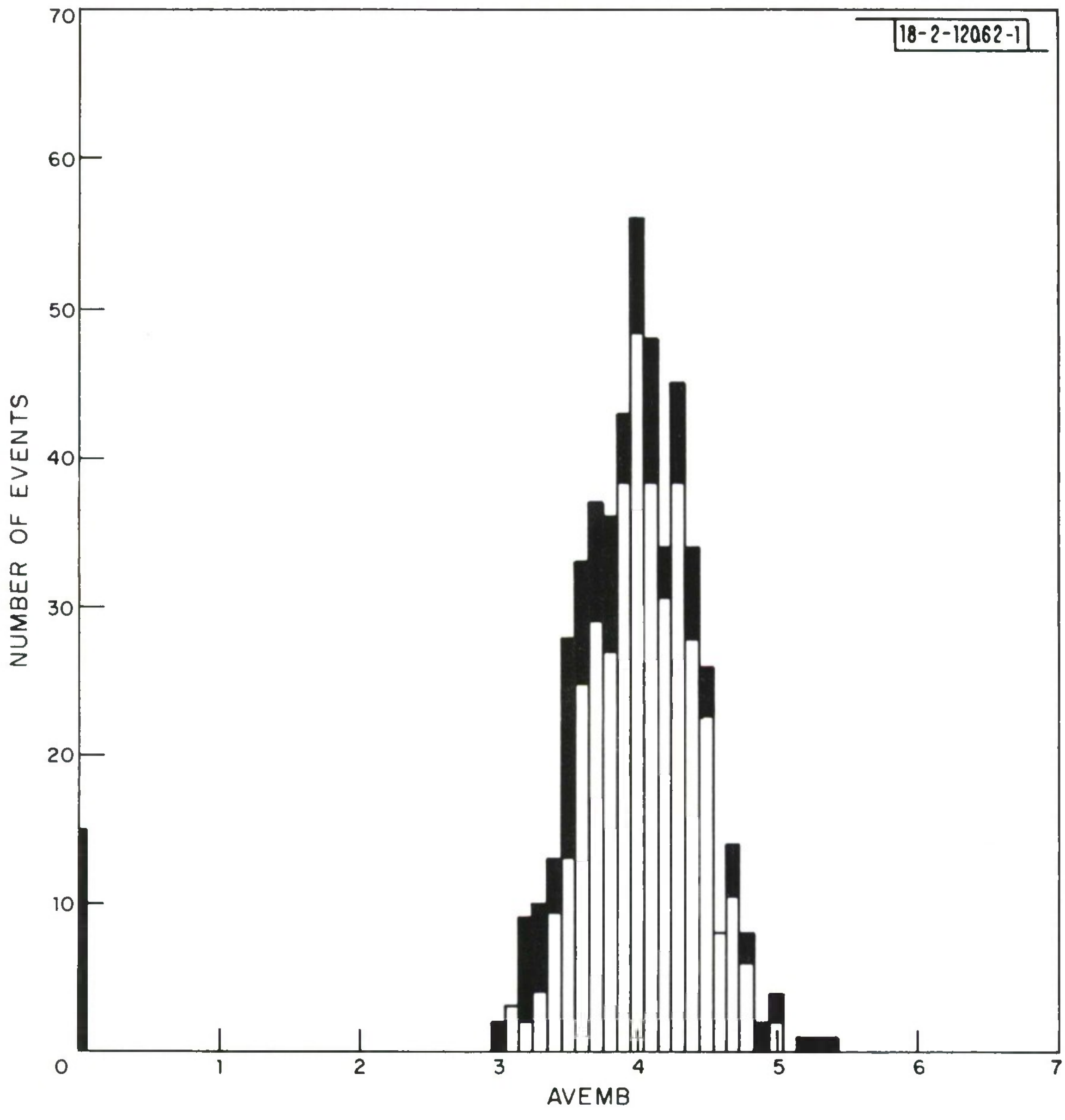

Fig. 4. Magnitude distribution of prototype network events not reported by PDE.

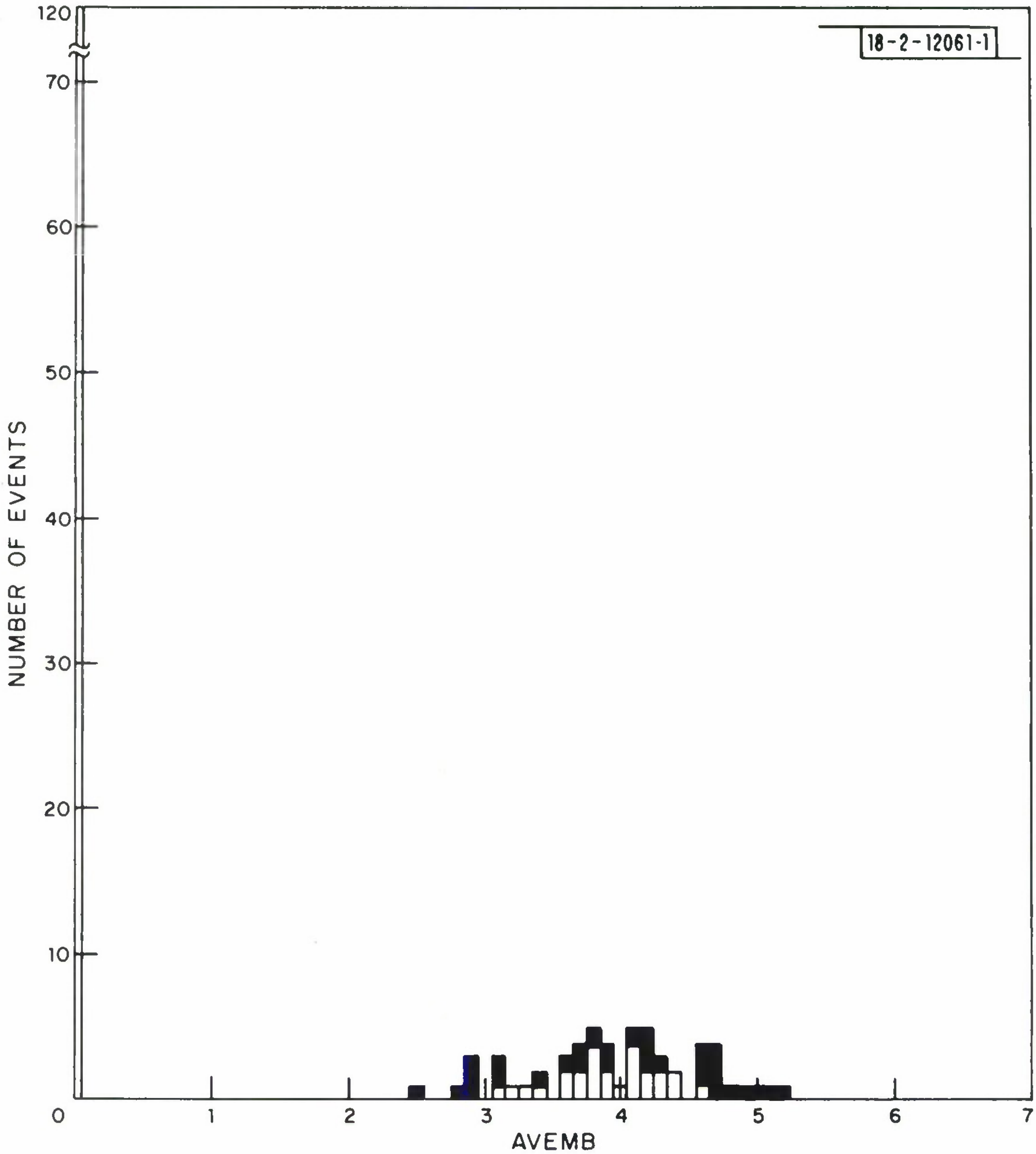

Fig. 5. Magnitude distribution of ISM events not reported by the prototype network.

comparison of the 460 32-station event epicenters to common events of the 787 ISM events was made. Figure 6 shows the epicenter errors obtained from this comparison, which indicate that 96% of these events have locations within 1° of the ISM epicenters.

The following conclusion can be made from these event list comparison statistics. (1) A large network of stations approximately 1/4 the size of the USGS network, such as the ISM network, using improved detection methods from less than 20% of its stations and using different event acceptance criteria can vastly increase the number of reported events in the magnitude range $<4.5\ m_b$ (Figure 3) without appreciable deterioration in epicenter location accuracy. (2) A small network of stations, such as the 32 station network, with approximately 30% of these stations reporting reread detections and using the event acceptance criteria required by the USGS, can not only increase the number of reported events but also have epicenters that are accurate to within approximately 1° of the PDE epicenters.

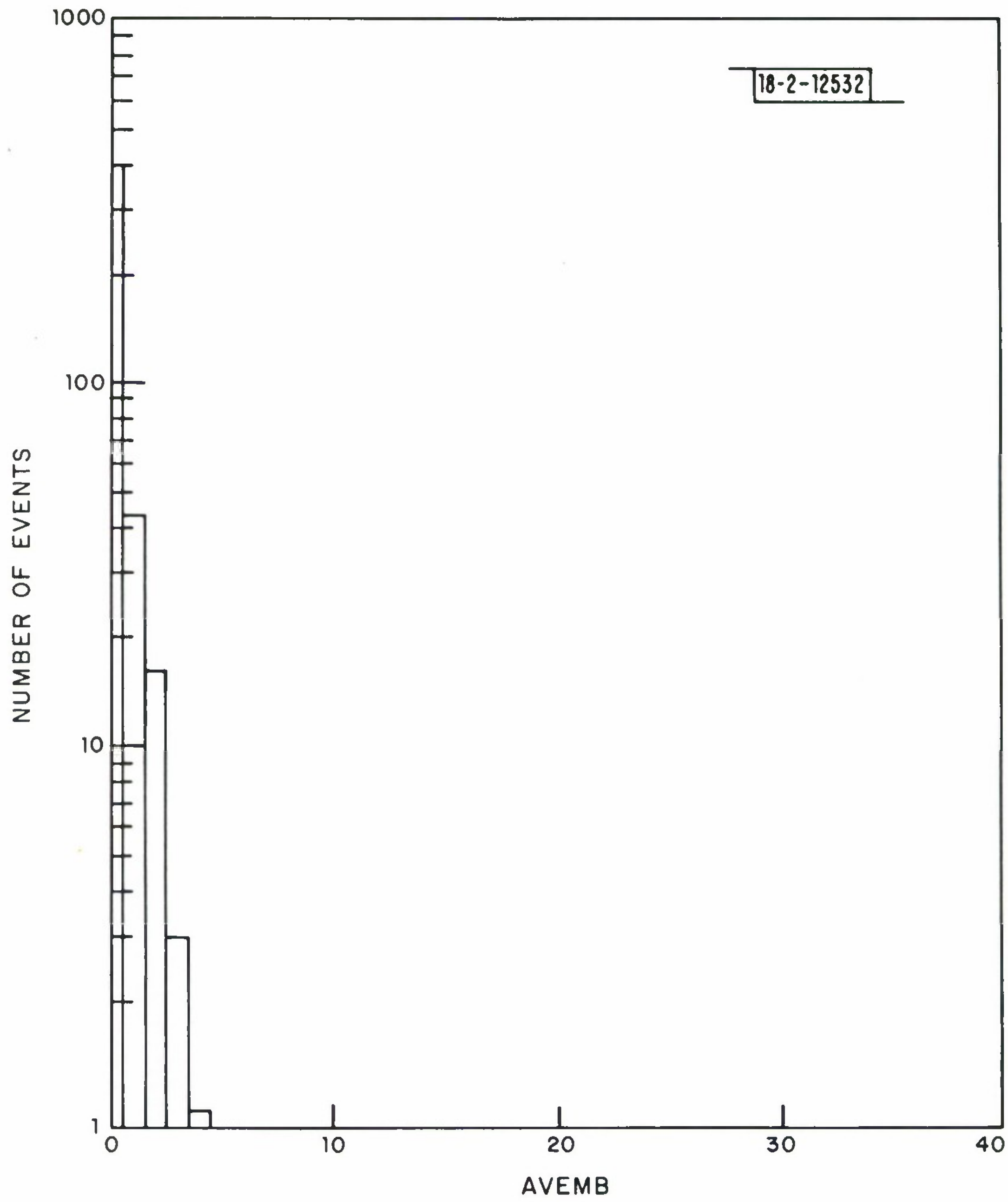

Fig. 6. Prototype network epicenter location errors.

Performance Improvements Resulting from Careful Rereading of Seismograms

Two stations of the 32 station network were selected to demonstrate by example how typical stations are not currently used to full capability. Stations MBC and KBL were chosen as stations whose data was reported to both the USGS and the ISM experiment. The detections from MBC reported to the ISM were reread by members of the Canadian Department of Energy, Mines and Resources, while those from KBL were reread by an analyst of the Lincoln Laboratory group. A comparison was made of the detections reported to the USGS and to the ISM experiment for ISM events $20^\circ \leq \Delta < 90^\circ$ from each of these stations. We also restricted the study to events with an ISM average magnitude determined by at least two stations to eliminate confusion resulting from poor m_b values. Figure 7 shows the ISM magnitude distribution of all ISM events within this distance range for station MBC. The dotted shading of this histogram denotes the events for which detections were sent from the station to the USGS for their use. The cross line shading indicates additional detections obtained by the more thorough reading of MBC seismograms which was done for the ISM. For magnitudes of < 5.0 m_b, one notes a large increase in the number of associated detections obtained by rereading. Figure 8 shows the associated detections of Figure 7 converted into cumulative percentage of ISM events. The dips observed on the cumulative curves for magnitude greater than 5.0 m_b are due to a few missed events and are probably an artifact resulting from the small sample size for these larger magnitudes. This artifact makes it difficult to precisely

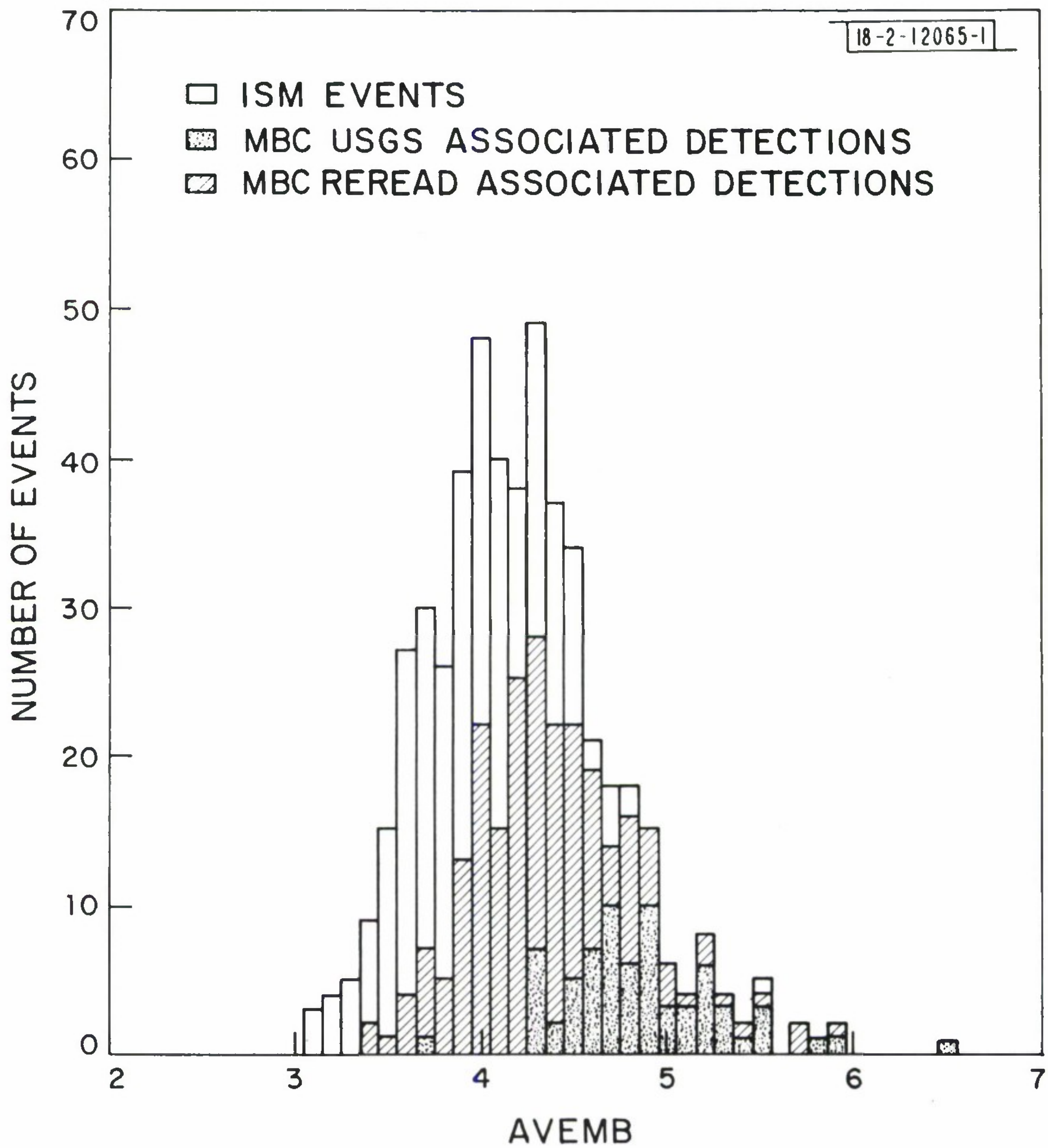

Fig. 7. Magnitude distribution of events 20° Δ<90° from MBC.

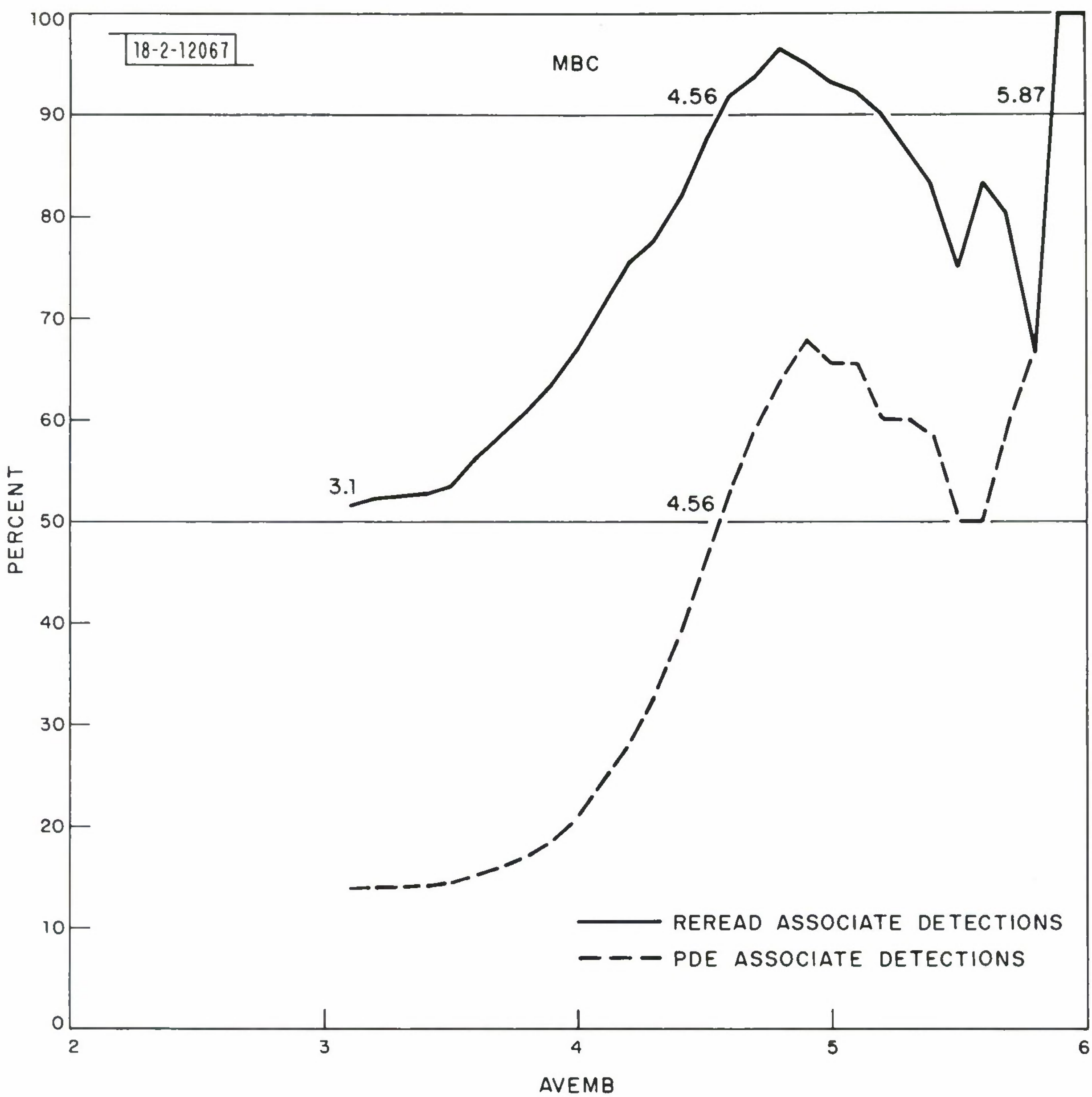

Fig. 8. Cumulative percentage of ISM events for MBC detections.

compare detection levels. Nevertheless it seems clear that both the 50% and 90% detection thresholds are at least 1.0 m_b units lower for the reread data.

The same comparison was made for station KBL, which according to NEIS[6] (National Earthquake Information Service) of the USGS was one of the better reporting stations for PDE computations. The event to station distance restraints and the number of station m_b values required to compute average m_b were the same for KBL as was stated for MBC. Figure 9 shows this comparison. The improvement in the number of events associated with the reread detections is significant for m_b's < 4.5. Figure 10 shows the cumulative detection curves for KBL. The 90% cumulative detection threshold did not change but an improvement of ≈ 0.8 m_b units at the 50% level is clear. Although some improvement was obtained by rereading the seismograms from station KBL, it is not as great as that obtained by rereading the seismograms from station MBC.

Now suppose that all of the non-array stations in the 32 station network had been read as carefully as possible. What would be the capability of such a network? To address this question we chose limit ourselves to events with magnitudes $4.6 \leq m_b < 4.7$ (the 90% cumulative detection threshold of the ISM experiment[5]). There were 38 events in this magnitude range on the ISM list. Of these only 24 were used on the USGS PDE list. Table 2 shows individual station detection statistics for these 38 events. The detection percentages given are based only on the subset of events within 90° of the particular station. The number

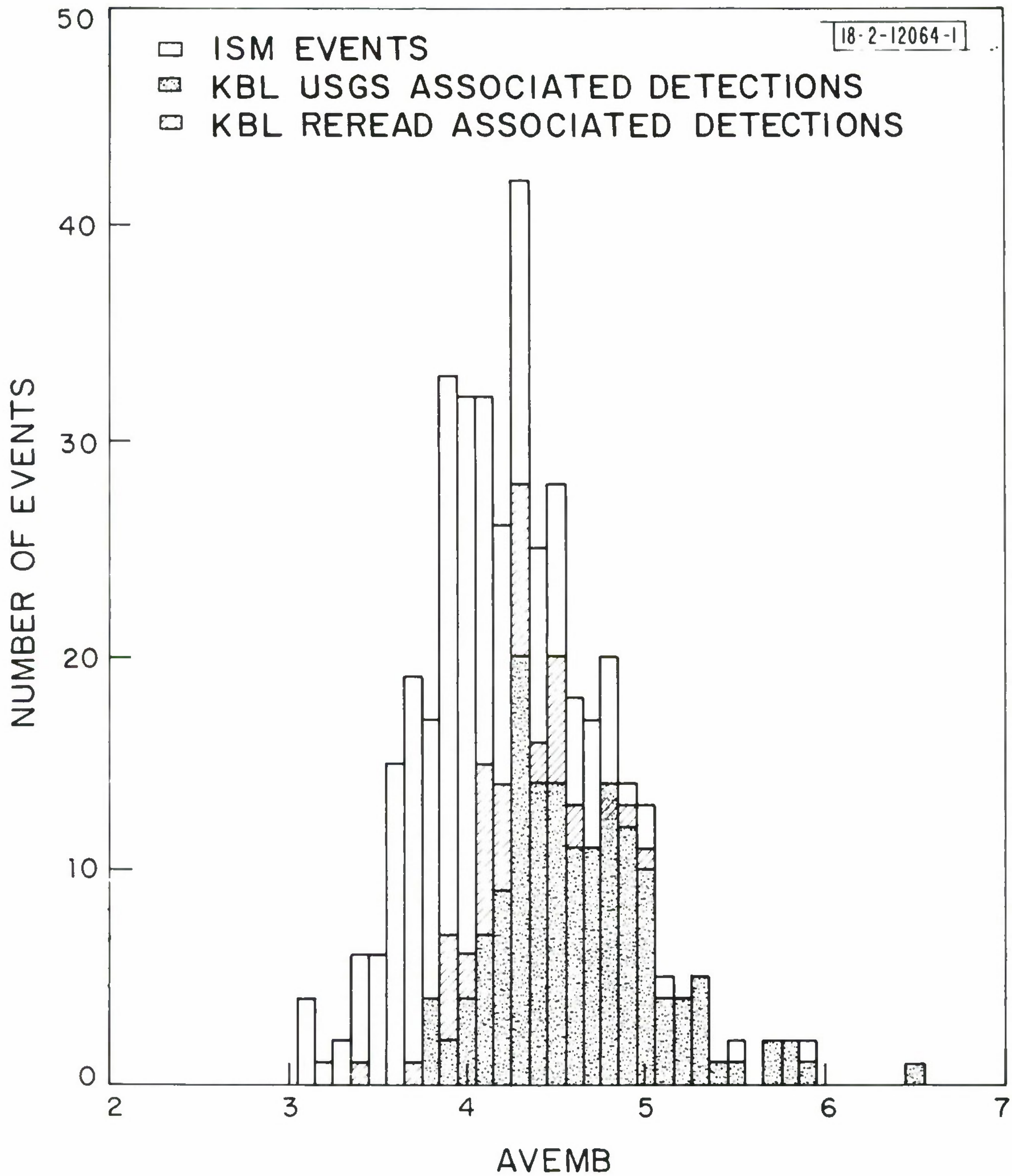

Fig. 9. 3agnitude distribution of events 20° Δ<90° from KBL.

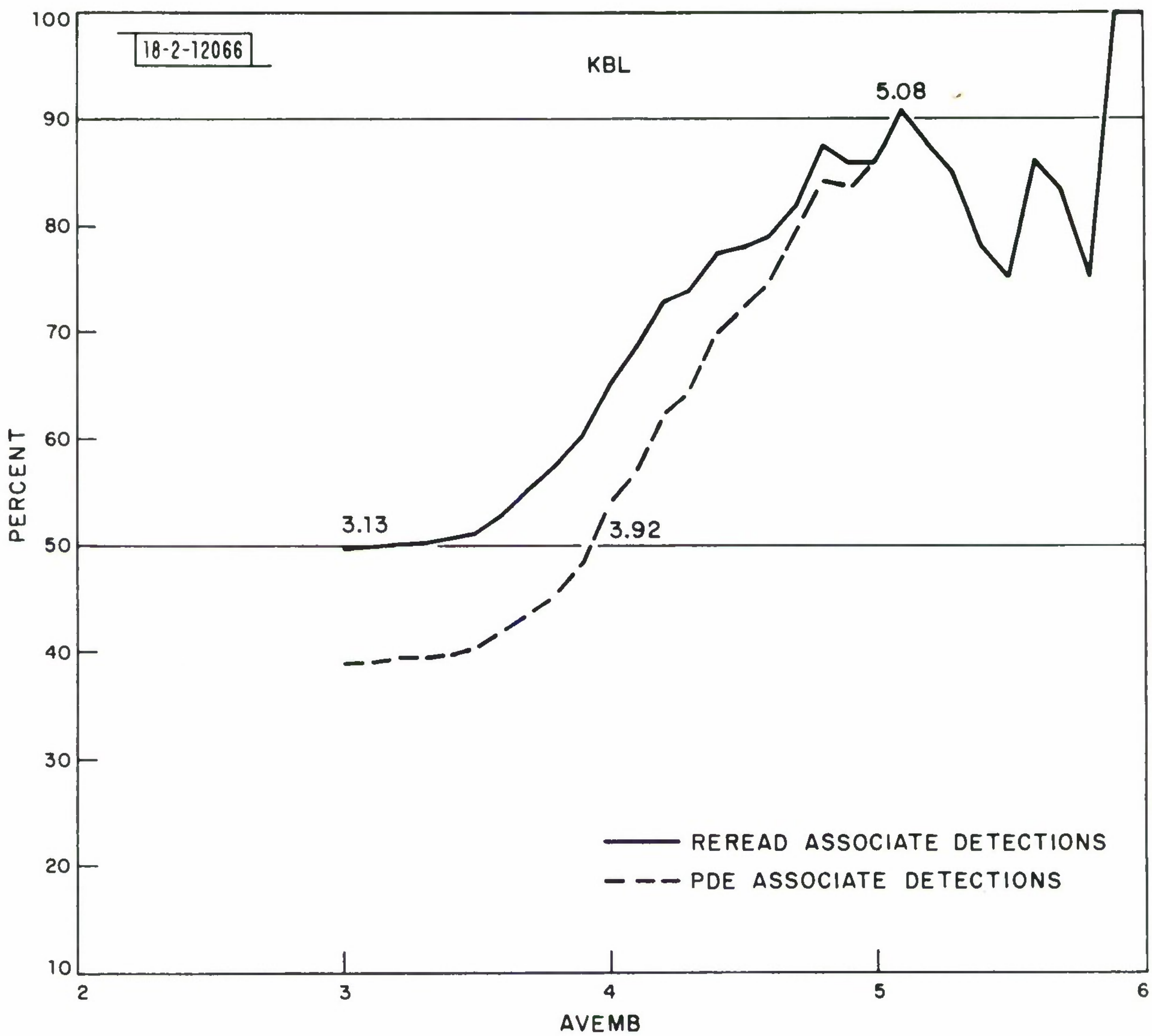

Fig. 10. Cumulative percentage of ISM events for KBL detections.

of events within 90° of each station is presented in column 1. Column 2 indicates the number of these events which had detections reported to the USGS. Column 3 is just the ratio of column 2 to column 1. This ratio is our estimate of the probability that the station will report an arrival to the USGS for an event in the 4.6 m_b magnitude range which is less than 90° from the station. The average probability is 0.35. Column 4 is the same as column 2 but for the detections used in the ISM experiment. Column 5 is our estimate detection probability based upon data available for the ISM. The average probability in this case is increased to 0.44. The average station probability improvement for the ISM is caused by the lower detection threshold of only 9 of the 32 stations (denoted by * in column 4). For this experiment, 12 additional stations of the 32 station network were reread from film chips making a total of 21 of the 32 stations being reread. Film chips were not available to us for the remaining 11 stations denoted with a +. Column 6 is similar to 2 and 4 but for this most complete visual analysis of the available seismograms. Column 7 is the station detection probability estimated from 1 and 6. The average probability is now .563 and if only the 21 stations that were actually reread are averaged the average probability is .665.

An attempt was made to locate the 38 ISM events with $4.6 \leq m_b < 4.7$ using these various sets of detections at the 32 station network. We used both the USGS PDE event acceptance criteria and the ISM experiment event acceptance criteria. Tables 3 and 4 show the results.

Table 2

Station Detection Statistics

Station	1 No. Events $4.6 \leqslant M_b < 4.7$ $\Delta \leqslant 90°$	2 Reported To USGS	3 USGS Station Probability	4 Reported To ISM	5 ISM Station Probability	6 This Experiment	7 Final Station Probability
LAO	16	11	0.688	15*	0.939	15*	0.939
YKA	24	0	0.000	14*	0.583	14*	0.583
UBO	17	12	0.706	12	0.706	12†	0.706
NAO	21	15	0.714	19*	0.905	19*	0.905
HFS	22	9	0.409	14*	0.636	14*	0.636
MBC	20	7	0.350	15*	0.750	15*	0.750
KBL	21	11	0.524	13*	0.619	13*	0.619
ASP	27	19	0.704	19	0.704	19†	0.704
MAT	32	10	0.313	10	0.313	23*	0.719
COL	30	15	0.500	15	0.500	23*	0.767
CHG	27	0	0.000	13*	0.481	20*	0.741
PNS	8	1	0.125	1	0.125	1†	0.125
CTA	29	17	0.586	17	0.586	17†	0.586
BLC	18	5	0.279	9*	0.500	9†	0.500
NUR	20	10	0.500	10	0.500	13*	0.650
TUC	17	4	0.235	4	0.235	10*	0.588
FBC	17	2	0.119	10*	0.588	10*	0.588
GBA	20	8	0.400	8	0.400	8†	0.400
SPA	16	9	0.563	9	0.563	15*	0.938
PMG	28	10	0.357	10	0.357	16*	0.571
KIC	10	5	0.500	5	0.500	5†	0.500
CLL	21	6	0.286	6	0.286	6†	0.286
SSF	16	4	0.250	4	0.250	4†	0.250
BDF	8	3	0.375	3	0.375	3†	0.375
BNG	9	5	0.556	5	0.556	5†	0.556
QUE	21	6	0.273	6	0.273	12	0.571
SHI	17	1	0.059	1	0.059	9*	0.591
BAG	31	6	0.194	6	0.194	14*	0.452
BUL	9	2	0.222	2	0.222	8*	0.899
AFI	31	5	0.161	5	0.161	9*	0.290
EZN	17	1	0.059	1	0.059	1†	0.059
SHL	25	2	0.080	2	0.080	17*	0.680
			0.347		0.436		0.563 0.665 Stations†

*Reread Stations

†Film Chips Not Available At Lincoln Laboratory for Rereading

Table 3

32 Station Set Detection Capability

32 Station Detection Set	Average Station Probability	No. of 38 Events Located Using PDE Acceptance Criteria	%	No. of 38 Events Located with ISM Acceptance Criteria	%
PDE	.347	21	55.3	30	78.9
ISM	.436	29	76.3	36	94.7
Reread ISM	.563	36	94.7	38	100.0

Table 4 shows the location capability achieved using only the 21 stations reread for this experiment.

Table 4

21 Station Set Detection Capability

Detection Set	Average Station Probability	No. of 38 Events Located Using PDE Acceptance Criteria	%	No. of 38 Events Located with ISM Acceptance Criteria	%
21 STA	.665	32	84.2	35	92.1

These data verify again that careful reading and processing of 20-30 well placed stations can generate a significantly larger event list than obtained by current USGS practice which makes use of many more stations. Our data establishes this for $4.6 \leq m_b < 4.7$ where the USGS reporting probability is low (24/38 = .63). For higher magnitudes the difference would decrease since the USGS reporting probability would increase toward 1.0. Probably the difference would be larger for smaller events if we exclude events in the USGS list which are based upon only local data. Of course, acceptance criteria also significantly alters event list detection thresholds, especially with low detection probabilities for individual stations. These acceptance criteria also affect location accuracy but we have not addressed this question here.

Examples of additional detections that were obtained by rereading film chips are shown in Figure 11 for QUE. Station QUE was chosen not as an example of poor reading and reporting but as an average reporting station. Additional detections for 6 events of the 38 with reliable m_b values were obtained by rereading this station. These reread detections are the result of hindsight picking but at least 4 of these events are quite obvious. Three additional events not shown in this figure could have possibly been reported by a well trained analyst.

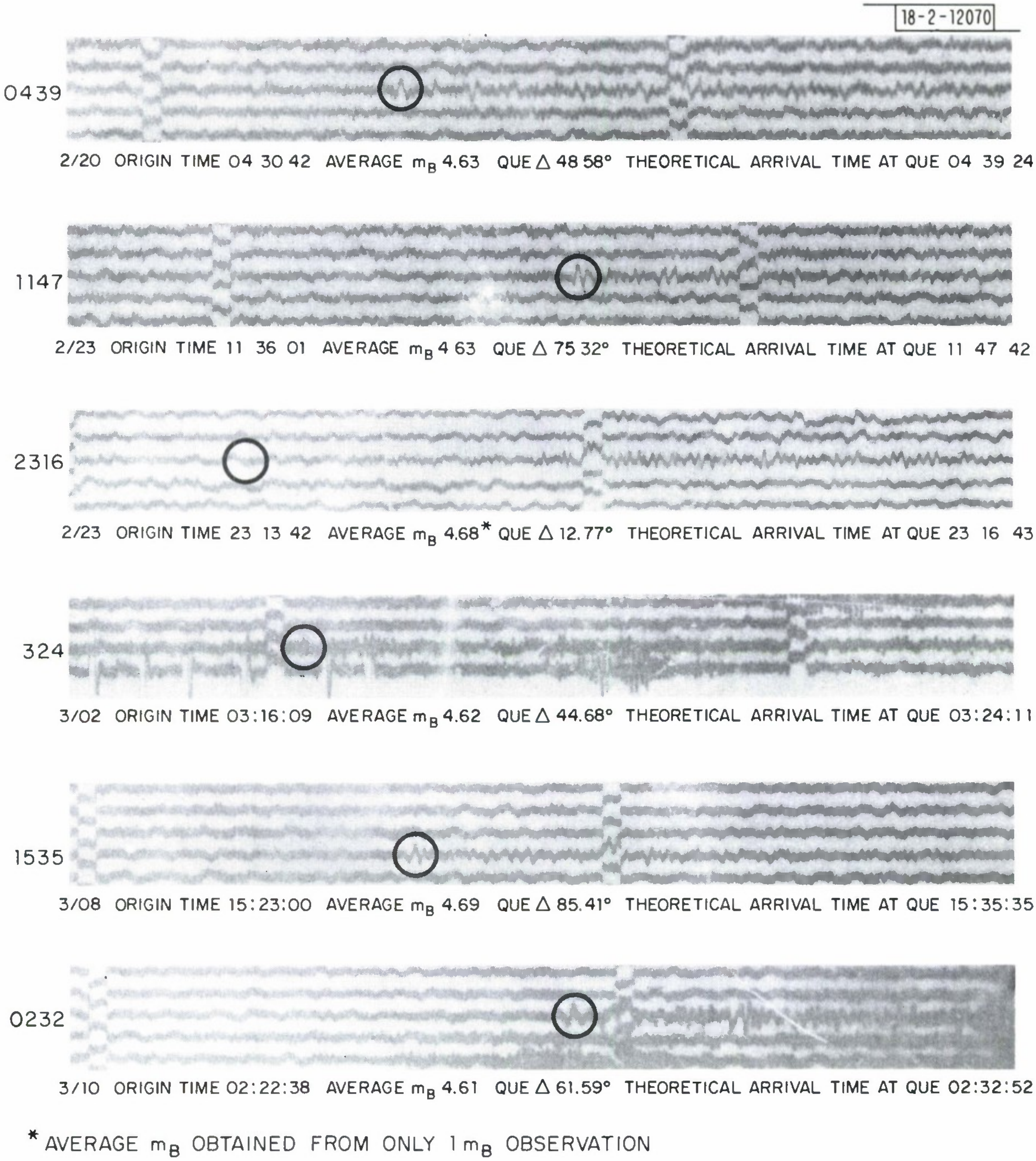

Fig. 11. Additional detections obtained rereading station QUE film chips.

Network Detection Probability

A simple statistical model to predict the probability of an N station detection from an M station network with a known average station probability has been programmed to complement the experimental evaluation of small networks. The formula used for this model is as follows:

$$P = \sum_{k=N}^{M} \binom{M}{N} p^{k}(1-p)^{M-k}$$

where P is the probability of N or more detections of an event by M detectors if the detectors are independent and each has a probability p of detecting recognizing any particular event.

Suppose p = .630. This average station probability is the average of the best reported 16 stations of the 32 station network for events with $4.6 \leq m_b < 4.7$ which are within 90° of the station and is the approximate average one would achieve if all of the 32 station network stations were reread. Using the model with this average station probability, a network detection probability table has been generated and is shown as Table 5. An example of the use of this table is as follows. Suppose that half of the 32 stations are within 90° of a particular event. Then the probability of detection by 5 stations or more is 0.998. This drops to 0.907 for 8 or more and 0.625 for 10 or more. Of course the model could generate such a table for any average station probability. The particular table shown indicates that a 32 station

network should have a global detection capability of essentially 100% at m_b 4.6, which is the estimated 90% incremental detection threshold for the ISM list.

Table 5

Network Detection Probability

NUMBER OF DETECTION STATIONS

NUMBER OF STATIONS < 90° FROM EVENT	1	2	3	4	5	6	7	8	9	10	11
1	0.630										
2	0.863	0.397									
3	0.949	0.691	0.250								
4	0.981	0.854	0.528	0.158							
5	0.993	0.934	0.733	0.391	0.099						
6	0.997	0.971	0.860	0.606	0.283	0.063					
7	0.999	0.988	0.930	0.766	0.487	0.201	0.039				
8	1.000	0.995	0.966	0.869	0.663	0.381	0.141	0.025			
9	1.000	0.998	0.984	0.930	0.793	0.558	0.292	0.098	0.016		
10	1.000	0.999	0.993	0.964	0.879	0.706	0.460	0.221	0.068	0.010	
11	1.000	1.000	0.997	0.982	0.933	0.815	0.615	0.371	0.164	0.046	0.006
12	1.000	1.000	0.999	0.991	0.964	0.889	0.741	0.525	0.295	0.120	0.031
13	1.000	1.000	0.999	0.996	0.981	0.936	0.835	0.661	0.440	0.230	0.088
14	1.000	1.000	1.000	0.998	0.991	0.965	0.899	0.770	0.579	0.362	0.177
15	1.000	1.000	1.000	0.999	0.995	0.981	0.940	0.851	0.700	0.499	0.294
16	1.000	1.000	1.000	1.000	0.998	0.990	0.966	0.907	0.795	0.625	0.423
17	1.000	1.000	1.000	1.000	0.999	0.995	0.981	0.944	0.866	0.732	0.551
18	1.000	1.000	1.000	1.000	0.999	0.997	0.990	0.967	0.915	0.816	0.665
19	1.000	1.000	1.000	1.000	1.000	0.999	0.995	0.981	0.948	0.879	0.760
20	1.000	1.000	1.000	1.000	1.000	0.999	0.997	0.990	0.969	0.922	0.835
21	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.994	0.982	0.952	0.890
22	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997	0.990	0.971	0.929
23	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.994	0.983	0.955
24	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997	0.990	0.973
25	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.994	0.984
26	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997	0.990
27	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.994
28	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.997
29	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998
30	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999
31	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999
32	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

NUMBER OF STATIONS < 90° FROM EVENT	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
12	0.004																				
13	0.021	0.002																			
14	0.063	0.014	0.002																		
15	0.135	0.045	0.010	0.001																	
16	0.235	0.102	0.032	0.006	0.001																
17	0.353	0.186	0.076	0.022	0.004	0.000															
18	0.478	0.291	0.145	0.056	0.016	0.003	0.000														
19	0.596	0.409	0.237	0.112	0.041	0.011	0.002	0.000													
20	0.699	0.527	0.345	0.191	0.086	0.030	0.008	0.001	0.000												
21	0.785	0.635	0.459	0.288	0.152	0.065	0.022	0.005	0.001	0.000											
22	0.851	0.730	0.570	0.396	0.238	0.120	0.049	0.016	0.004	0.001	0.000										
23	0.900	0.806	0.671	0.506	0.338	0.194	0.094	0.037	0.011	0.002	0.000	0.000									
24	0.935	0.865	0.756	0.610	0.444	0.285	0.157	0.073	0.027	0.008	0.002	0.000	0.000								
25	0.959	0.909	0.825	0.702	0.548	0.385	0.237	0.126	0.056	0.020	0.006	0.001	0.000	0.000							
26	0.974	0.940	0.878	0.779	0.645	0.488	0.330	0.196	0.100	0.043	0.015	0.004	0.001	0.000	0.000						
27	0.984	0.962	0.917	0.842	0.730	0.587	0.429	0.281	0.161	0.079	0.032	0.011	0.003	0.001	0.000	0.000					
28	0.991	0.976	0.945	0.889	0.800	0.677	0.529	0.374	0.236	0.130	0.062	0.024	0.008	0.002	0.000	0.000	0.000				
29	0.995	0.985	0.965	0.925	0.856	0.754	0.622	0.472	0.323	0.197	0.105	0.048	0.018	0.006	0.001	0.000	0.000	0.000			
30	0.997	0.991	0.978	0.950	0.899	0.819	0.705	0.566	0.417	0.277	0.163	0.084	0.037	0.014	0.004	0.001	0.000	0.000	0.000		
31	0.998	0.995	0.986	0.967	0.931	0.869	0.777	0.654	0.511	0.365	0.234	0.134	0.066	0.028	0.010	0.003	0.001	0.000	0.000	0.000	
32	0.999	0.997	0.992	0.979	0.954	0.908	0.835	0.731	0.601	0.457	0.317	0.197	0.109	0.052	0.022	0.007	0.002	0.000	0.000	0.000	0.000

Single-station probability = 0.63.

Conclusions and Discussions

A network consisting of a small number (2-3) of arrays and (20-30) traditional seismic stations could be used to routinely produce a global seismic bulletin (excluding local events) better than those now produced on a routine basis by USGS or the large arrays.

A list of events produced using data from this small network would have better hypocenter control than do lists produced by the individual seismic arrays. The small network could be used to locate considerably more events than the current PDE operation does without sacrificing hypocenter accuracy.

A most significant step towards achieving the potential capability of a small network would be simply to arrange for uniform and careful reading of seismograms from a few tens of good stations reasonably distributed about the globe. Some potential advantages of the better quality control on the data submitted from stations of this small network, other than the increased number of detections, would be more amplitude and period measurements used to compute station m_b's, more first motion measurements, and more secondary phase data.

The question of what improvement better or different instrumentation for the stations of this network may have on the detection capability of the network was not addressed by this report.

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An investigation into the detection capability of a prototype seismic network has been completed. This investigation was threefold in nature. The first investigation was a comparison of event lists; second, the effect of careful reading of seismograms was determined; and, finally, a simple statistical model was programmed to predict the probability of an N-station detection from an M-station network with a known average station probability.

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